International Journal of Mechanical and Production
Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 9, Issue 2, Apr 2019, 399-406

A STUDY ON AL_2O_3 – H_2O NANO FLUID IN THE PRESENCE OF CONSTANT HEAT SOURCE

J. L. RAMA PRASAD[1], K. S. BALAMURUGAN[2] & G. DHARMAIAH[3]

[1]*Department of Mathematics, PB Siddartha college of Arts and Science, Vijayawada, Andhra Pradesh, India*

[2]*Department of Mathematics, RVR & JC College of Engineering, Chowdavaram, Guntur, Andhra Pradesh, India*

[3]*Department of Mathematics, Narasaraopeta Engineering College, Yellamanda, Narsaraopet, Andhra Pradesh, India*

ABSTRACT

MHD stream of a nanofluid Al2O3 past an oscillatory moving vertical porous semi-unending level surface with consistent heat source in a rotating frame of reference is analyzed. The arrangements of the boundary layer conditions are accepted of oscillatory sort and they are gotten by utilizing the perturbation technique. The effect of various physical characteristics such as magnetic parameter (M), heat source parameter (QH), rotation parameter(R), volumetric nano-particle (ϕ) and suction parameter(S) are presented and discussed.

KEYWORDS: Constant Heat Source, MHD, Al2O3-H2O & Convection Flow

Received: Dec 14, 2018; **Accepted:** Jan 16, 2019; **Published:** Mar 04, 2019; **Paper Id.:** IJMPERDAPR201938

Original Article

1. INTRODUCTION

The suspension of nanoparticles, for example, Al_2O_3, TiO_2, SiO_2, Ag, Cu or CuO in the base fluids like ethylene glycol, oil or water is known as the nano fluids. The analysts who are doing research recently, have given careful consideration to investigate the properties of nanofluid. It is a direct result of higher thermal execution and their potential job for high thermal trade and with zero weight drop. A mixture of nano fluid with biotechnical parts has been broadly utilized in different agrarian, organic sensors and pharmaceuticals forms. Diverse sorts of nanomaterials like nanofibers, nanostructures, nano wires and nanomachines are used in the biotechnological applications. The nanofluids can likewise be associated with thermal expulsion framework and the backup security frameworks. The heat exchange upgrade attributes of nanofluid are very helpful in the atomic reactor forms and atomic reactor security frameworks. As of late, the supportable vitality cohort is likewise a testing issue internationally. The solar radiation is the most appropriate possibility for the sustainable power source with less ecological effect. By the usage of solar power, heat, water and power can be specifically acquired from nature. The researchers and scientists have investigated that the solar authority procedures and heat exchange rate can be enhanced through the expansion of nano particles in the base liquids. Nano materials are the new vitality materials in light of the fact that their size is comparative or littler than the cognizant or de Brogile waves. The nano particles are most appropriate to firmly ingest the episode radiation. Because of such properties of nano materials, the nano fluid in sun powered thermal framework is another examination territory for the analysts and specialists. Different favorable circumstances of the use of nano fluids incorporate the enhanced warmth exchange, heat exchange framework estimate decrease, smaller scale channel cooling and scaling down of the framework. The Nanofluids are of nanometer estimated particles that are metals, oxides, carbides or carbon nanotubes. The properties of Nanofluids are of exceptional significance over the base liquid since warm conductivity and convective properties

of the Nanofluid overwhelming over the properties of the base liquid. The basic base liquids incorporate water, ethylene glycol, toluene and oil. Thermal conductivity is seen to be all the more successfully upgraded in the scope of 15% - 40% over the base liquid. Another technology medium, called nanofluid evoke in a wide scope of scientists on many cooling forms in building applications, for example in transportation, atomic reactor, hardware just as biomedicine and sustenance. The term nanofluid mentions to a fluid suspension containing minor particles having the distance across under 50 nm. Cho [1] analyzed the softening heat transfer passes within the sight of laminar flow over a level surface. Kazmierczak et al. [2, 3] communicated the impacts of convective flow on liquefying from a vertical plate. Gorla et al. [4] explained the convection impact on liquefying from a vertical plate. Liquefying consequences for blended convective warmth exchange stream from a vertical plate were clarified by Cheng and Lin [5– 7]. Heat transfer attributes initiated by a constantly moving surface are critical in modern building procedures, for example, in the polymer business, overlay and melting spin process. The impact of thermal radiation on flow and heat transfer forms is of significant significance in the plan of many propelled vitality change frameworks working at high temperature. Thermal radiation inside such frameworks happens as a result of the discharge by the hot dividers and working fluid. In modern innovation and geothermal application, high-temperature plasmas appropriate to atomic combination vitality transformation, fluid metal fluids and power generation frameworks. With regards to exothermic or endothermic substance responses, in heat convection, where there may exist a high temperature contrasts between the surface and the surrounding liquid the warmth source/sink impact are increasingly critical. The investigation of magnetohydrodynamic stream is major in light of the fact that the impact of an attractive field on the gooey stream of electrically leading liquid is fundamental in numerous mechanical procedures, for example, in attractive materials handling, decontamination of unrefined petroleum, MHD electrical power age, glass assembling, geophysics and paper creation. The magnetohydrodynamic is one of the essential factors by which the cooling rate can be controlled and the result of the ideal quality can be accomplished. Ishak et al. [8] talked about the thermal exchange stream over a softening and moving surface. Limit layer execution on consistent mixing surface was first expected by Sakiadis [9, 10]. Das [11] examined dissolving impacts on MHD stream over a liquefying and moving surface within the sight of radiation. Satya Narayana et al. [12] investigated MHD stream of micropolar liquid in a turning framework. The significance of heat exchange attributes flow of an extending surface has been produced by [13– 23]. The point is to investigate the impact of strong volume portion parameter ϕ on the stream and heat exchange attributes for various nanoparticles considered.

2. MATHEMATICAL MODEL

We assumed a temperamental three-dimensional stream of an electrically leading incompressible nanofluid past a semi-infinite vertical porous plate. A uniform outer attractive field B_0 is taken to act along the z* axis. It is expected that there is no connected voltage which suggests the absence of an electric field. The stream is thought to be in the x* – course which is brought the plate the upward way and z* direction is ordinary to the plate. Additionally it is expected the entire framework is turned with a consistent vector Ω about the z*-axis. The flow is dim, retaining emanating however not dissipating medium. The radiation heat transition in x*-direction is viewed as immaterial in correlation that in the z*-course. Because of semi-endless plate surface presumption the stream factors are elements of z and time t only. Assumed that the normal flow and the suspended nano particles are in heat harmony and no slip happens between them.

Boundary layer approximations, the boundary layer equations governing the fluid flow, temperature and concentration along with the Boussinesq are,

$$\frac{\partial w^*}{\partial z^*} = 0 \tag{1}$$

$$\frac{\partial u^*}{\partial t^*} + w^*\frac{\partial u^*}{\partial z^*} - 2\Omega v^* = \frac{\mu_{nf}}{\rho_{nf}}\frac{\partial^2 u^*}{\partial z^{*2}} + \frac{[\rho\beta]_{nf}}{\rho_{nf}} g(T - T_\infty) - \frac{1}{\rho_{nf}}\sigma B_0^2 u^* \tag{2}$$

$$\frac{\partial v^*}{\partial t^*} + w^*\frac{\partial v^*}{\partial z^*} + 2\Omega u^* = \frac{\mu_{nf}}{\rho_{nf}}\frac{\partial^2 v^*}{\partial z^{*2}} - \frac{1}{\rho_{nf}}\sigma B_0^2 v^* \tag{3}$$

$$\frac{\partial T}{\partial t^*} + w^*\frac{\partial T}{\partial t^*} = \alpha_{nf}\frac{\partial^2 T}{\partial z^{*2}} - \frac{Q^*(T - T_\infty)}{[\rho Cp]_{nf}} \tag{4}$$

The boundary conditions for the problem are given by

$$u^*(z^*, t^*) = 0,\ v^*(z^*, t^*) = 0,\ T = T_\infty,\ for\ t^* \le 0\ and\ any\ z^* \tag{5}$$

$$u^*(\infty, t^*) = U_0\left[1 + \frac{\varepsilon}{2}(e^{\mathrm{in}^*t^*} + e^{-\mathrm{in}^*t^*})\right],\ T(\infty, t^*) \to T_\infty,\ for\ t^* \ge 0 \tag{6}$$

Here u*, v* and w* are the velocity components along the x*, y* and z* axis respectively.

The properties of nanofluids which are given by (Oztop and Abu-Nada [24])

$$\rho_{nl} = (1-\phi)\rho_l + \phi\rho_s, (\rho Cp)_{nl} = (1-\phi)(\rho Cp)_l + \phi(\rho Cp)_s,$$
$$(\rho\beta)_{nl} = (1-\phi)(\rho\beta)_l + \phi(\rho\beta)_s, \mu_{nl} = \frac{\mu_l}{[1-\phi]^{2.5}}, \alpha_{nl} = \frac{K_{nl}}{(\rho Cp)_{nl}}, \tag{7}$$
$$\frac{K_{nl}}{K_l} = \left[\frac{K_s + 2K_l - 2\phi(K_l - K_s)}{K_s + 2K_l + 2\phi(K_l - K_s)}\right]$$

The thermo physical properties of the base fluid (water) and other nanofluids are shown in Table 1.

Table 1: Nano Fluids and Their Thermo Physical Characteristics (Turkyilmanzoglu[25])

Nanofluids	Density (ρ)	Specific Heat (Cp)	Thermal Conductivity (k)	$\beta X10^{-5}$
Alumina(Al_2O_3)	3970	765	40	0.85
Pure water	997.1	4179	0.613	21

The solution of Equation (1) is considered as $w^* = -w_0$ (8)

Introducing dimensionless variables in the following manner,

$$u = \frac{u^*}{U}, v = \frac{v^*}{U}, z = \frac{z^*U}{\nu_f}, t = \frac{t^*U^2}{\nu_f}, n = \frac{\nu_f n^*}{U^2}, S = \frac{w_0}{U}, R = \frac{2\Omega\nu_f}{U^2}, Q_H = \frac{Q^*\nu_f^2}{K_f U^2}, \Pr = \frac{\nu_f(\rho Cp)_f}{K_f} \tag{9}$$

Using (9), Equations 2-4 can be converted into dimensionless form and in order to get the desired solutions, we can express the fluid velocity in complex form then solved under boundary conditions in the neighborhood of the surface using perturbation technique, we obtain the velocity and temperature in the following manner.

$$\chi(z,t) = p_3 e^{-r_1 z} + p_4 e^{-r_2 z} + p_5 e^{-r_3 z} + \frac{\varepsilon}{2}\left\{e^{-r_4 z}\ e^{\mathrm{int}} + e^{-r_5 z}\ e^{-\mathrm{int}}\right\} \tag{10}$$

$$\theta(z,t) = p_1 e^{-r_1 z} \tag{11}$$

The skin-friction rate and rate of heat transfer are given by

$$C_f = \frac{1}{(1-\phi)^{2.5}} \chi'(0), Nu = -\frac{K_{nl}}{K_l} \theta'(0) \tag{12}$$

3. RESULT ANALYSIS

A hypothetical report on the impact of nanoparticle Al_2O_3 on MHD free convection stream along a vertical semi-infinite level plate with heat source when the plate swinging in time t within the sight of a turning casing of reference has been performed. In the present examination the accompanying default parameter esteems are embraced. n=10, nt = $\pi/2$, Pr = 6.72, ε = 0.001, K = 0.5, Kr = 0.5, M = 1, Q_H = 10, R = 0.02, S = 1, ϕ = 0.10. The impacts of nanoparticles on the flow of fluid and the temperature profiles just as on the skin friction coefficient and the neighborhood Nusselt number are examined. The impact of the suction parameter S on the nanofluid speed profiles for the Al_2O_3-water nano liquid particles are represented in Figure 1. It is seen that an expansion in S adds to the abatement in the nanofluid velocity dispersion. The impact of revolution parameter R on the nanofluid speed profiles for various estimations of Al_2O_3 nanoparticles is appeared in Figure 2. From the figure, we see that the nanofluid velocity conveyance over the boundary layer diminishes with an expansion of R. The impact of heat source parameter on the nanofluid speed dissemination for different estimations of Al_2O_3 nanoparticles is appeared in Figure 3. From the figure, we see that the nanofluid speed over the boundary layer diminishes with an expansion of QH. Figures 4 and 8 separately, delineates the impact of the nanoparticle volume part on the speed and temperature profiles. Obviously as the nanoparticle volume portion expands, the nanofluid speed increments and temperature conveyances increments. This concurs with the physical conduct that, when the volume portion of Al_2O_3 builds, the thermal conductivity increments, and after that the warm boundary layer thickness increment. Figure 5 presents average profile for the nanofluid velocity profiles for various estimations of attractive field parameter M. From the diagram, clearly the nanofluid velocity of the fluid flow decelerates with increment in the quality of attractive field. The impacts of a transverse attractive field on an electrically directing flow offer ascent to a resistive-type drive called the Lorentz compel. This power tends to back off the movement of the flow in the boundary layer. These outcomes subjectively concur with the desires, since attractive field applies hindering power on the normal convection stream. Figures 6 shows the impact of the suction parameter S on the temperature profile. It very well may be seen that the nanofluid temperature profile decline with the expansion of the suction parameter. This demonstrates the standard actuality that the suction balances out the boundary development. Figure 7 demonstrates the nanofluid temperature profile for various estimations of heat generation parameter Q_H. From the chart, obviously there is a diminishing in the nanofluid temperature profiles with an expanding in Q_H. From Table 2, obviously with the expanding estimations of S, ϕ and Q_H, the coefficient of skin-friction is expanding and with the expanding estimations of M and R, the coefficient of skin-friction is diminishing. From Table 3, it is seen that rate of heat transfer is increments with the expanding estimations of S, QH, Pr and ϕ.

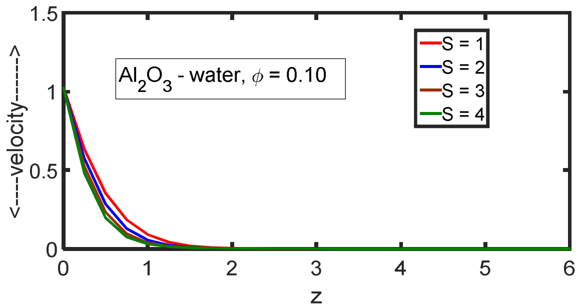

Figure 1: Velocity Profile Verses Suction(S) Values

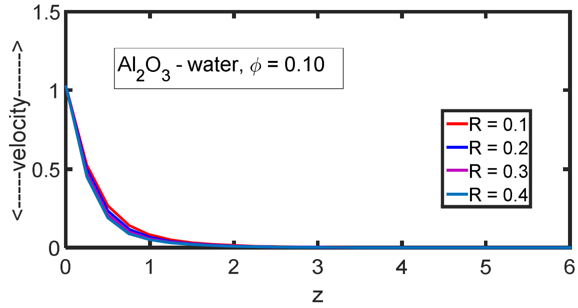

Figure 2: Velocity Profile Verses Rotation Parameter(R) Values

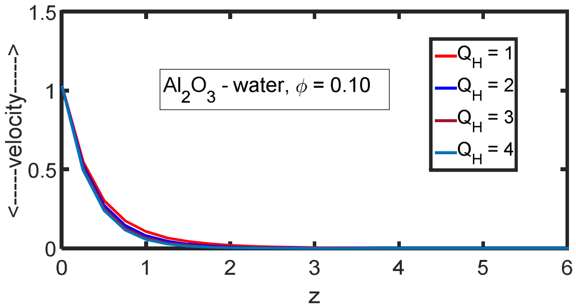

Figure 3: Velocity Profile Verses Heat Source Parameter(QH) Values

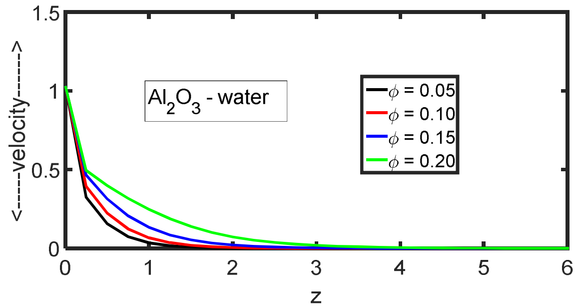

Figure 4: Velocity Profile Verses Volume Fraction(ϕ) Values

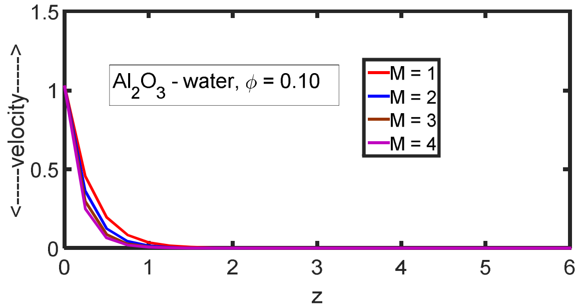

Figure 5: Velocity Profile Verses Magnetic Parameter(M) Values

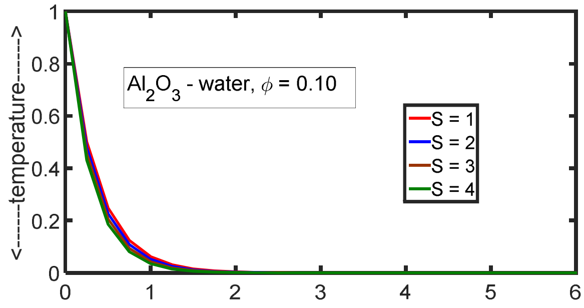

Figure 6: Temperature Profile Verses Suction(S) Values

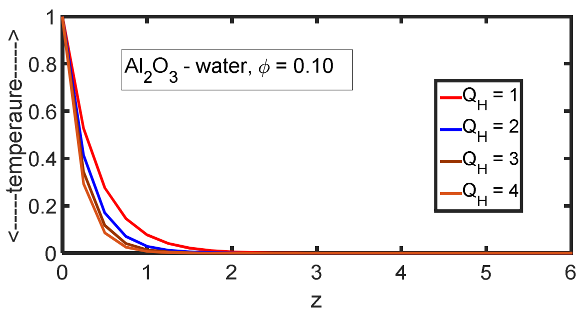

Figure 7: Temperature Profile Verses Heat Source Parameter(QH) Values

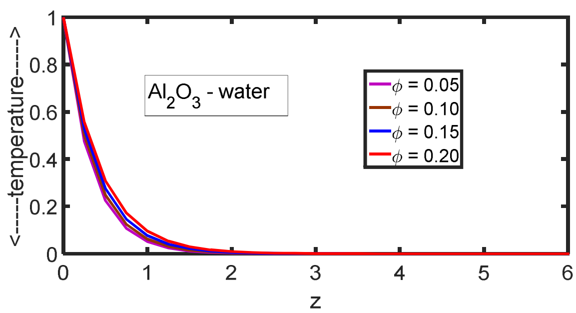

Figure 8: Temperature Profile Verses Volume Fraction(ϕ) Values

Table 2: Skin-Friction Values for Different Parameters

M	Q_H	R	S	ϕ	Cf
1					1.3526
2					1.3045
3					1.0768
4					0.9041
	0.2				1.3596
	0.3				1.3666
	0.4				1.3736
	0.5				1.3804
		2			0.5155
		3			0.2958
		4			0.2192
		5			0.1886
			0.2		2.7500
			0.3		4.2622
			0.4		5.9484
			0.5		7.8756
				0.05	0.3716
				0.10	0.5508
				0.15	0.7164
				0.20	0.8618

Table 3: Nusselt Values for Different Parameters

Pr	Q_H	S	ϕ	Nu
1				0.9367
2				1.7122
3				2.5185
4				3.3341
	0.1			0.7288
	0.2			0.8351
	0.3			0.9237
	0.4			1.0013
		0.2		1.2553
		0.3		1.8160
		0.4		2.3886
		0.5		2.9664
			0.05	1.1921
			0.10	1.6835
			0.15	2.1854
			0.20	2.6924

4. CONCLUSIONS

In this work, we have theoretically studied the effect of constant heat source on unsteady MHD free convection heat transfer flow of an incompressible, Al_2O_3-water based nano fluid along a semi-infinite vertical flat surface in a rotating frame of reference. The effects of various parameters on velocity, temperature and concentration profiles are discussed through graphs. The following are the conclusions derived from the present investigation.

- As S increases, the nanofluid velocity also decreases.
- As the M increases, the nanofluid velocity decreases.
- An increase in ϕ contributes to the increase in the nanofluid velocity and temperature distributions.

- It is clear from the graphs that all the nanofluid velocity and temperature profiles decreases with increase of Q_H.

REFERENCES

1. *Epstein, M., Cho, D.H. (1976). Melting heat transfer in steady laminar flow over a flat plate. J. Heat Transfer, 98, 333-531.*
2. *Kazmierczak, M., Poulikakos, D., Pop, I. (1986). Melting from a flat plate in a porous medium in the presence of steady convection. Numer. Heat Transfer, 10, 571–581.*
3. *Kazmierczak, M., Poulikakos, D., Sadowski, D. (1987). Melting of a vertical plate in porous medium controlled by forced convection of a dissimilar fluid. Int. Commun. Heat Mass Transfer, 14, 507–517.*
4. *Gorla, R.S.R., Mansour, M.A., Hassanien, I.A., Bakier, A.Y. (1999). Mixed convection effect on melting from a vertical plate. Transp. Porous Media, 36, 245–254.*
5. *Cheng, W.T., Lin, C.H. (2006). Transient mixed convection heat transfer with melting effect from the vertical plate in a liquid saturated porous medium. Internat. J. Eng. Sci., 44, 1023–1036.*
6. *Cheng, W.T., Lin, C.H. (2007). Melting effect on mixed convective heat transfer with aiding and opposing external flows from the vertical plate in a liquid saturated porous medium. Int. J. Heat Mass Transfer, 50, 3026–3034.*
7. *Cheng, W.T., Lin, C.H. (2008). Unsteady mass transfer in mixed convective heat flow from a vertical plate embedded in a liquid-saturated porous medium with melting effect. Int. Commun. Heat Mass Transfer, 35, 1350–1354.*
8. *Ishak, A., Nazar, R. Bachok, N., Pop, I. (2010). Melting heat transfer in steady laminar flow over a moving surface. Heat Mass Transfer, 46, 463–468.*
9. *Sakiadis, B.C. (1961). Flow and heat transfer in the boundary layer on a continuous moving surface. AIChE J., 7, 26–28.*
10. *Sakiadis, B.C. (1961). Boundary layer behavior on continuous solid surface II. The boundary layer on a continuous flat surface. AIChE J.,7, 221–225.*
11. *Kalidas, D. (2014). Radiation and melting effects on mhd boundary layer flow over a moving surface. Ain Shams Eng. J.*
12. *Satya Narayana, P.V., Venkateswarlu, B., Venkataramana, S. (2013) Effects of hall current and radiation absorption on MHD micropolar fluid in a rotating system. Ain Shams Eng. J., 4, 843–854.*
13. *Erickson, L.E., Fan, L.T., Fox, V.G. (1966). Heat and mass transfer on a moving continuous flat plate with suction or injection. Ind. Eng. Chem. Fund., 5, 19–25.*
14. *Tsou, F.K., Sparrow, E.M., Goldstein, R.J. (1967). Flow and heat transfer in the boundary layer on a continuous moving surface. Int. J. Heat Mass Transfer, 10, 219–235.*
15. *Fox, V.G., Erickson, L.E., Fan, L.T. (1968). Methods for solving the boundary layer equations for moving continuous flat surfaces with suction and injection. AIChE J., 14, 726–736.*
16. *Gupta, P.S., Gupta, A.S. (1977). Heat and mass transfer on a stretching sheet with suction or blowing. Can. J. Chem. Eng., 55, 744–746.*
17. *Soundalgekar, V.M., Ramana Murty, T.V. (1980). Heat transfer past a continuous moving plate with variable temperature. Warmeund Stoffu bertragung, 14, 91–93.*
18. *Grubka, L.G., Bobba, K.M. (1985). Heat transfer characteristics of a continuous stretching surface with variable temperature. ASME J. Heat Transfer,107, 248–250.*
19. *Chen, C.K., Char, M.I. (1988). Heat transfer of a continuous stretching surface with suction or blowing. J. Math. Anal. Appl.,*

135, 568–580.

20. *Ali, M.E. (1994). Heat transfer characteristics of a continuous stretching surface. Warmeund Stoffu bertragung, 29, 227–234.*
21. *Magyari, E., Keller, B. (1999). Heat and mass transfer in the boundary layers on an exponentially stretching continuous surface. J. Phys. D: Appl. Phys., 32, 577–585.*
22. *Magyari, E., Keller, B. (1999). Heat transfer characteristics of the separation boundary flow induced by a continuous stretching surface. J. Phys. D: Appl. Phys., 32, 2876–2881.*
23. *Magyari, E., Ali, M.E., Keller, B. (2001). Heat and mass transfer characteristics of the self-similar boundary-layer flows induced by continuous surfaces stretched with rapidly decreasing velocities. Heat Mass Transfer, 38, 65–74.*
24. *Oztop, H.F., Abu-Nada, E. (2008). Numerical study of natural convection in partially heated rectangular enclosures filled with nanofluids. Int J Heat Mass Transf, 29, 1326–1336.*
25. *Turkyilmanzoglu, M. (2016). Natural Convective Flow Of Fluids Past A Radiative And Impulsive Vertical Plate. J. Aerosp. Eng., 29, 1-8.*